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I was unable to secure any photographs, though a friend kindly tried to take some for me, our ladder proving too short to admit of getting the camera into position for focussing; but the rough drawing made on the spot with the aid of an opera-glass may give a better idea of the feeding position assumed by the mother bird than my description has done.

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THE MECHANICS OF SOARING.

BY PROFESSOR J. E. HENDRICKS.

As Mr. I. Lancaster has published, through the medium of the AMERICAN NATURALIST, his very interesting and valuable observations of soaring birds, and has, in the April number (No. 4, Vol. xx) given an explanation of the mechanics of soaring that might lead non-technical readers astray, a brief review of the "Mechanics of Soaring" may not be unprofitable to some of the readers of the NATURALIST.

As much that Mr. Lancaster has said is in accordance with the recognized principles of mechanics, I will not encumber the pages of the NATURALIST with a general review of the whole article, but will confine this paper mainly to a consideration of the question proposed by him and which he regards as a crucial test of the validity of his theory of soaring.

In investigations concerning the operation of forces, it is important that the distinction between continuous and momentary forces be kept in view. Although all forces require time for their operation, yet such forces as act for a short time and then cease to act, are called *momentary* forces, and the time during which they act is not considered; the velocity induced being constant and equal to the intensity of the force divided by the mass.

When a force acts uniformly for a considerable portion of time, it is called a *constant* force, and the time of its action is involved in the velocity it induces, which is represented by the intensity of the force multiplied by the time and divided by the mass or weight of the body.

Although we do not know what produces the phenomena of gravitation, we know, as manifested on the surface of the earth, it is a result of two opposing forces (a centripetal and a centrifugal force) whose difference at any point on the earth's surface is indicated by the weight of the body at that point. Weight, therefore, or gravity, is a constant force, and differs in no respect from any other constant force.

It is found by experiment that a current of air, having a velocity of thirty feet per second, and meeting a stationary plane, the projection of which, in the direction of the motion, has a superficial area of one square foot, exerts upon the plane, in the direction of the current, a force $= 2$ lbs. $\times \sin^2 \theta$, where θ denotes the angle which the plane makes with the direction of the motion; and for different planes the force is approximately proportional to the areas of the planes, so that on a plane one foot wide and six feet long, as supposed by Mr. Lancaster, when the current is normal to the plane, the force exerted upon the plane by a velocity of thirty feet per second will be twelve pounds. This is the value of the special force assumed by Mr. Lancaster, and whether we consider the twelve pounds pressure as resulting from a constant atmospheric current or any other cause is obviously indifferent.

If then we suppose the weight of the plane to be twelve pounds, and its descent vertical through a quiescent atmosphere, while the plane surface is horizontal, the case will be that of a falling body in a resisting medium, and when the plane shall have acquired a velocity of thirty feet per second, we know, from the experiments above referred to, that the plane will meet a constant resistance of twelve pounds, and this being the weight of the plane it will thenceforth descend with the uniform velocity of thirty feet per second.

If while thus descending, in equilibrium, a momentary horizontal force, the intensity of which is equal to gravity, be impressed upon the plane, because it would impart to one pound a velocity of thirty-two feet per second, it will therefore impart to the plane, the weight of which is twelve pounds, a velocity of only $\frac{1}{12} \times 32$ ft., or $2\frac{2}{3}$ ft. per second, instead of 1000 ft. per second as assumed by Mr. Lancaster.

If now the plane be tilted so as to make an angle θ with the vertical, the vertical pressure it will encounter, when the velocity is thirty feet per second, will be $12 \sin^3 \theta$ lbs., and because its weight remains the same the plane will cease to be in equilibrium. An increase in the velocity of the descent of the plane in the ratio of $\sqrt{\sin^3 \theta} : 1$ would restore the equilibrium and the plane would descend along the "rest" with the uniform velocity of $\frac{30}{\sqrt{(\sin^3 \theta)}}$ feet per second.

We are now prepared to answer the query proposed by Mr. Lancaster as a crucial test of the validity of his theory, viz., "Will the tilted surface, supplied with the rest of two pounds and moving with uniform velocity, obey the impulse of an external force applied in its own plane with equal facility in any direction?"

The above formula for uniform velocity of descent indicates that, for all inclinations of the plane, there is an unbalanced force which acts downward and parallel with the face of the plane, and therefore toward the "rest." The tilted surface therefore will *not* "obey the impulse of an external force applied in its own plane with equal facility in any direction."

"The implication of the case" therefore is, that if an inclined plane is free to descend through the atmosphere, by virtue of its weight, it will, in consequence of the atmospheric resistance, move *laterally downward* unless it encounters a *current* of air that, being resolved by the under surface of the plane, gives a vertical component which is equal to or greater than the weight of the plane, in which case the plane will move horizontally or ascend; or if the plane is properly shaped it may, in consequence of "rear expansion" of the air, remain stationary with respect to the earth.

It follows that all of the observed phenomena of soaring are in accord with the recognized principles of mechanics, but I trust it is sufficiently obvious, from the preceding discussion, that a soaring bird is *not* "translated at right angles to the gravitating force, or horizontally, solely by the action of that force."

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EDITORS' TABLE.

EDITORS: A. S. PACKARD AND E. D. COPE.

—— Just as the inorganic appears to have preceded the organic in the history of the phenomena of nature, the inorganic preceded the organic as the most potent factor in the environment in which organic nature developed. Convulsions of inorganic nature were frequent and irresistible in the most ancient periods of time, and they diminished in number and importance as life